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Inertia, Stability, and the Future Grid

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Overview

- A power outage on 9 August 2019 raised questions about the ability of the national grid to withstand rapid changes in frequency caused by outages and surges on the network.
- This *inertia* has been changing in recent years due to the emergence of renewable energy generation as a significant contributor to the energy mix.
- Measures to mitigate this change need to be evaluated and the level of investment required to prevent a reoccurrence of such an event quantified.

An "incredibly rare event", "immense disruption" [1]

Lightning struck an overhead power line between Eaton Socon and Wymondley at 16:52.33 on Friday August 9, 2019 [2]. Two major generation units went offline almost immediately, followed by a cascade of outages that led to a cumulative power loss of 1,900MW. This exceeded the capacity of the reserves held to maintain the stability of supply. As a result, the power frequency, normally 50Hz, dropped to 48.8Hz — the lowest level measured in years — triggering exceptional measures intended to preserve the stability the overall network. 1.15m households were disconnected, thousands of commuters were turned away from train stations, while hospitals and airports also suffered disruptions. It took 5 minutes for the frequency to recover to normal levels, and 45 for all connections to be restored.

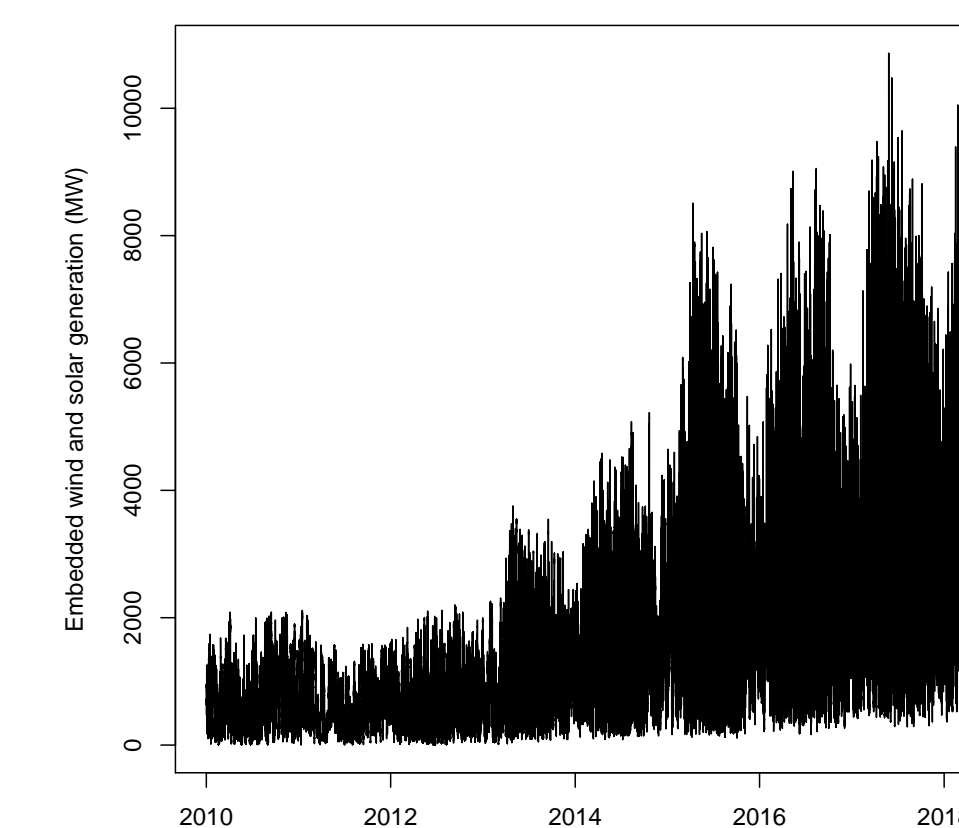
Inertia

The rotating mass of the turbines in thermal power plants resist changes in speed. Aggregated over the generators on the grid rotating synchronously, this system inertia mitigates rapid fluctuations in the frequency of the power supply from losses or surges in generation. Solar and wind power plants generate electricity directly, without the intermediate powering of a rotating turbine.



Steam turbine (Siemens)

Renewable Energy



GB grid renewables
2010-18 (Gridwatch)

Increasing dependence on renewable energy to meet demand has been matched by a reduction in the number of fossil fuel-powered plants — coal-fired generation has decreased from 70% in 1990 to 3% in 2020 [3]. This has led to a reduction in overall inertia and consequent vulnerability to rapid changes in frequency and instability of power supply.

Solutions

- Synchronous flywheel compensators
- Battery energy storage systems (BESS)
- Synthetic inertia from wind turbines
- Demand-side management
- Localized inertia measurement

Stability analysis

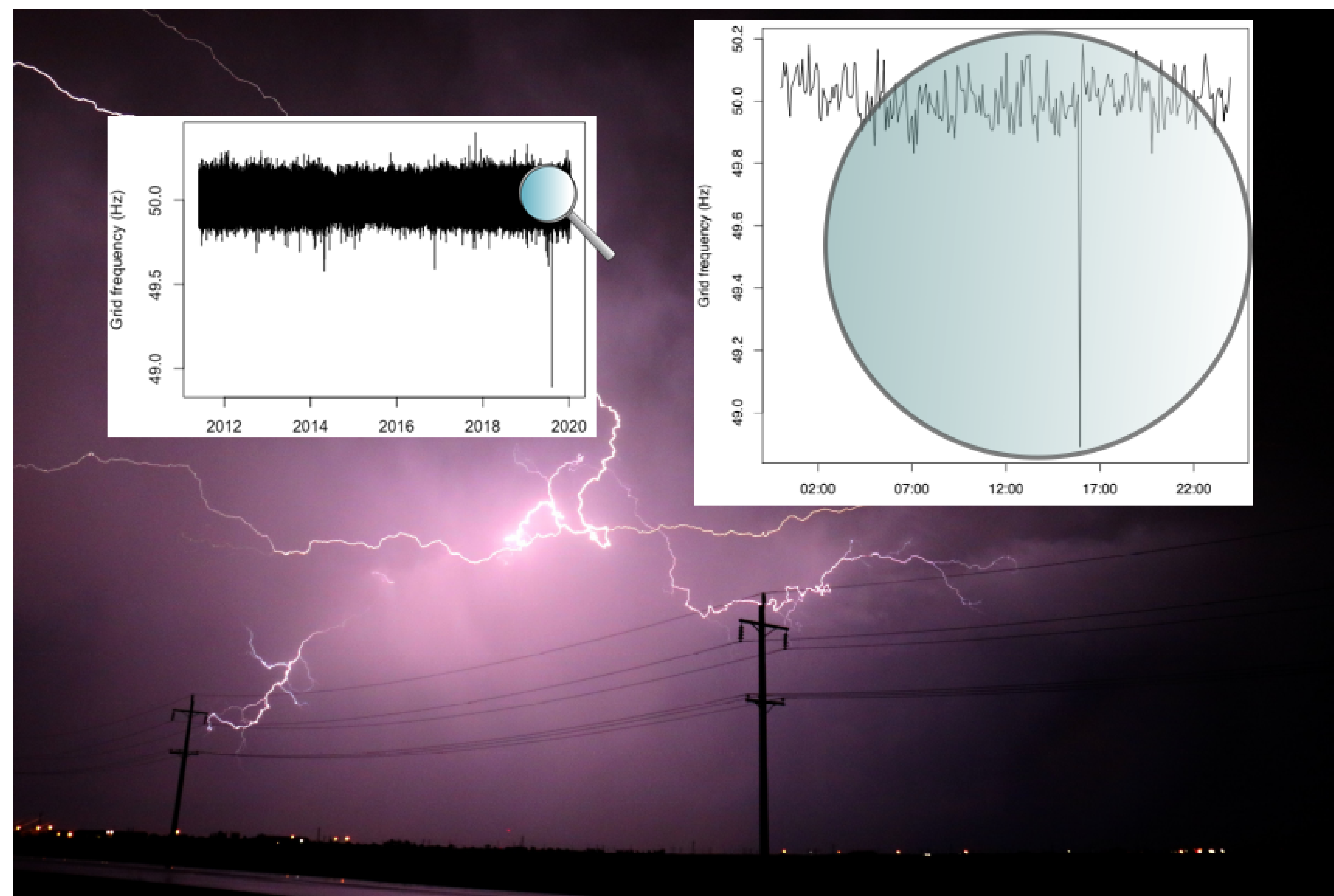
Models will need to be developed that simulate rapid changes in frequency, the effects of grid inertia, and the effectiveness of proposed measures in mitigating adverse outcomes.

Methodology

- Nonlinear dynamical systems and control theory
- Continuous-time differential-equation grid model
- Initial aggregate "Toy" model
- Stylized DC-Flow paradigm
- Networked AC-flow models
- Adaptive control

References

- [1] BBC News, *UK power cut: National Grid promises to learn lessons from blackout*, 10 August 2019
- [2] ESO, *Technical Report on the events of 9 August 2019*, 6 September 2019
- [3] BEIS(2020). *End of coal power to be brought forward in drive towards net zero*, Press Release, 4 February 2020



Historical grid frequency, 2011-19, August 9 2019, generated from Gridwatch data



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